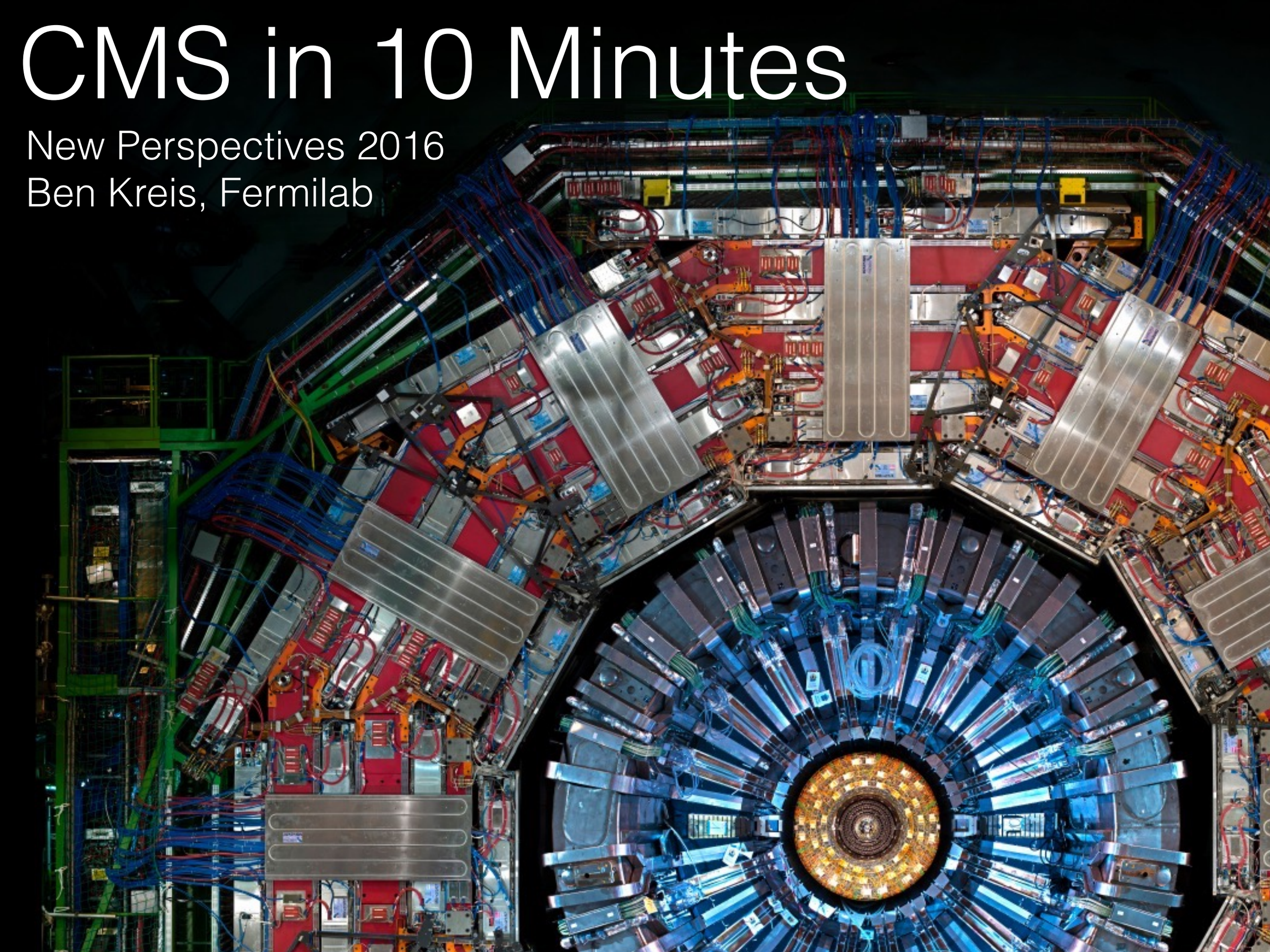
CMS in 10 Minutes

New Perspectives 2016

Ben Kreis, Fermilab



CMS Collaboration

life size picture of CMS hanging at CERN

2700 physicists, of which 900 are students!
860 engineers
280 technicians
from 182 institutes in 42 countries

USA is the largest national group with >700 members

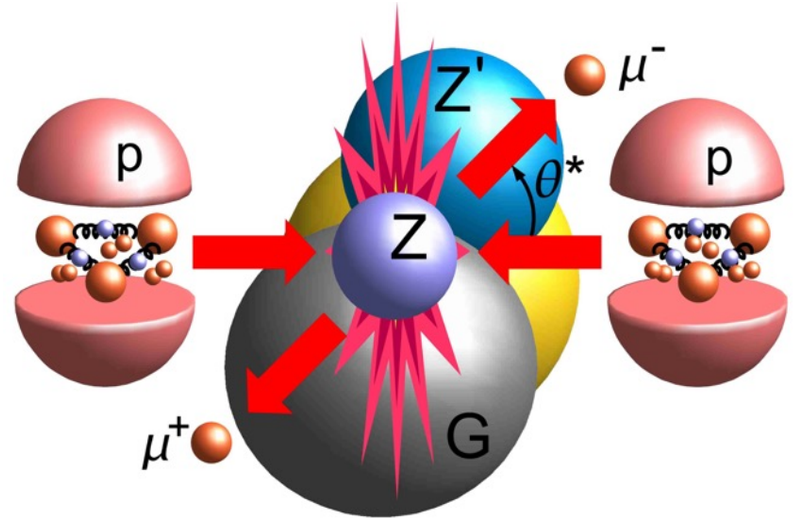
Large Hadron Collider (LHC)

LHC inner-triplet quadrupole:

Fermilab Today

Collides bunches of protons or heavy ions
~1e11 protons/bunch, ~50 simultaneous pp collisions
40 MHz collision rate
Up to 13 TeV center-of-mass energy

The highest energy collisions ever reached in a lab



Led to the discovery of the Higgs boson

Gives access to TeV-scale physics beyond the standard model

Supersymmetry

Dark matter

Extra Dimensions

Micro Black Holes

Gravitons

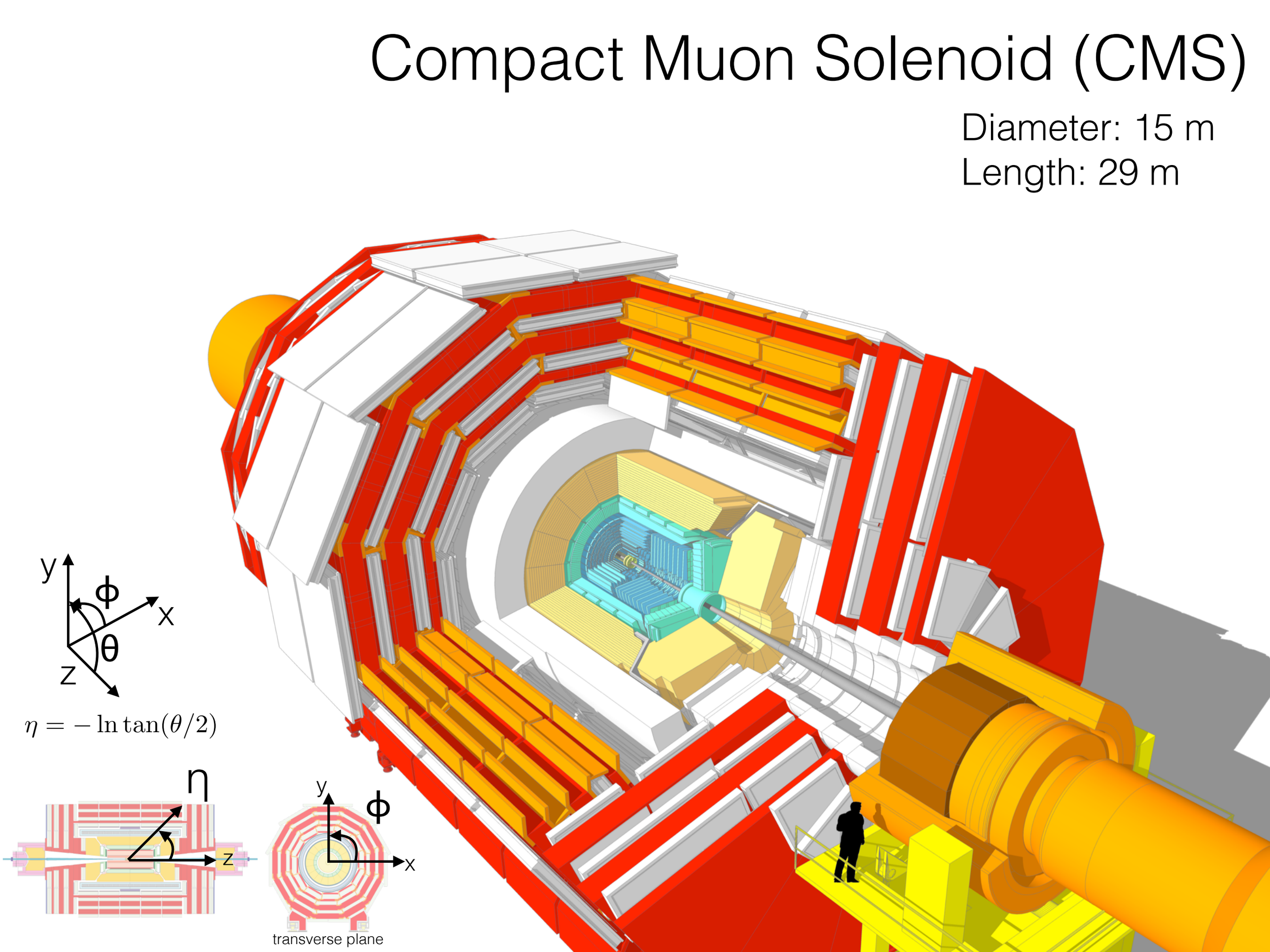
New symmetries and unification

Neutral Naturalness

you will hear about some of these in the next talks!

Compact Muon Solenoid (CMS)

Diameter: 15 m
Length: 29 m



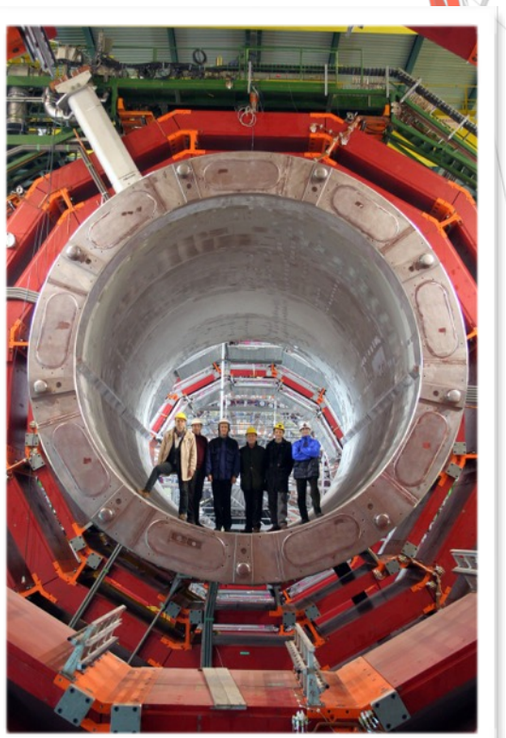
$$\eta = -\ln\tan(\theta/2)$$

transverse plane

Superconducting solenoid

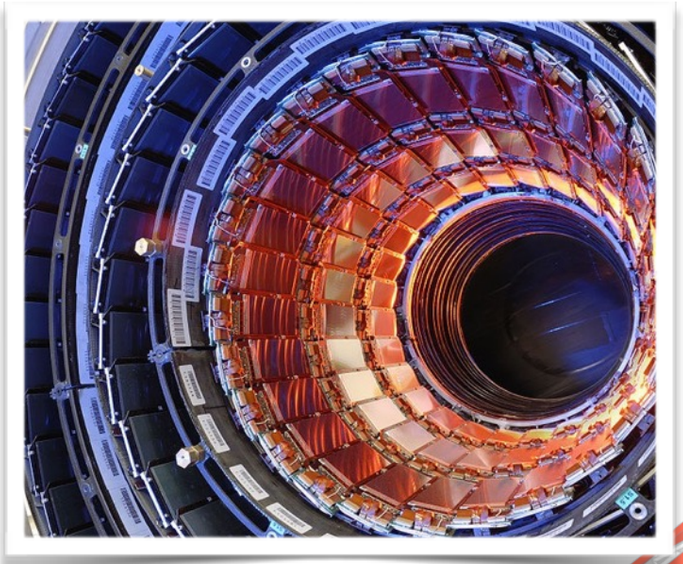
- Largest in the world
- B = 3.8 T
- Iron return yoke

$$\frac{mv^2}{r} = qvB \quad \Rightarrow r = \frac{mv}{qB}$$



transverse plane

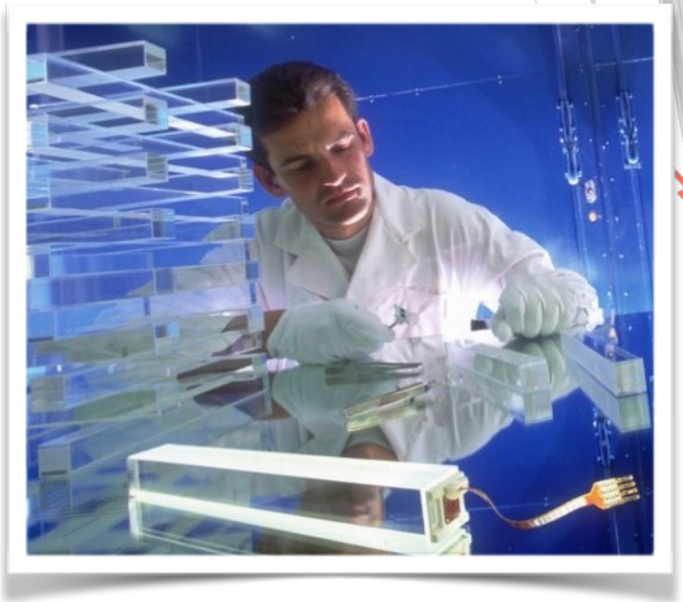
Inside the solenoid



About half of the tracker was built by the USA

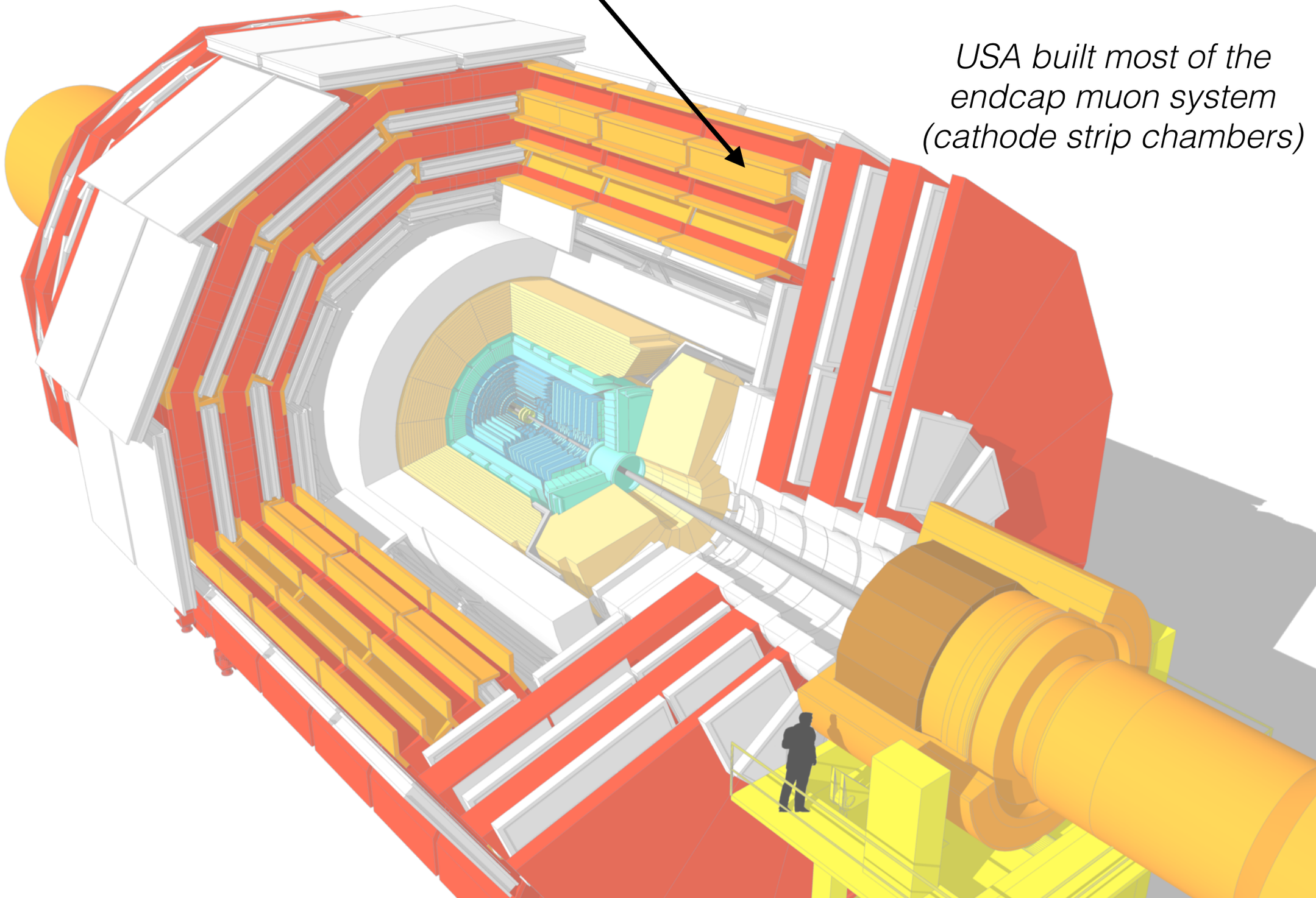
Silicon tracker
66 M pixels
10 M strips

Scintillating electromagnetic and hadronic calorimeters

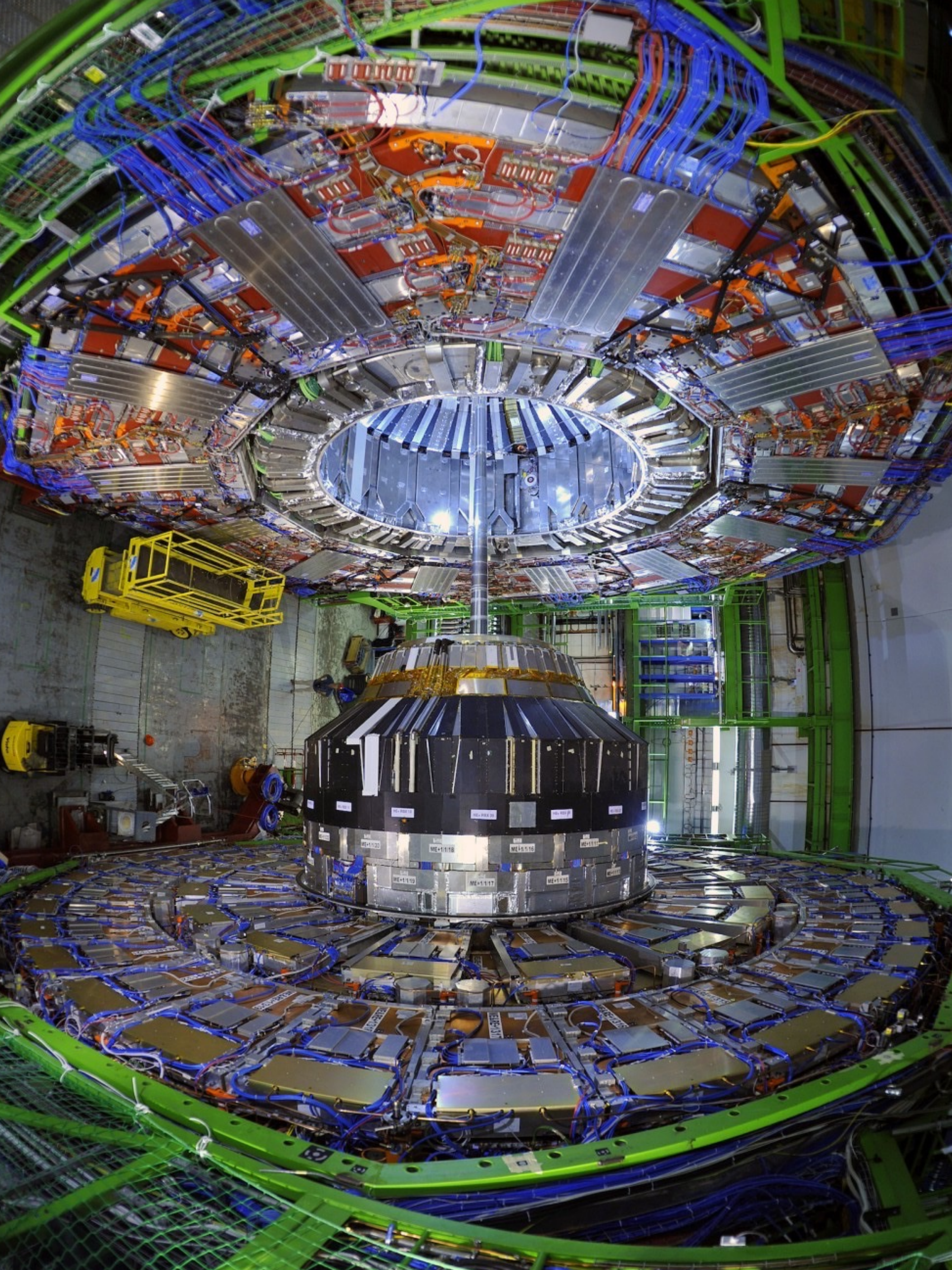


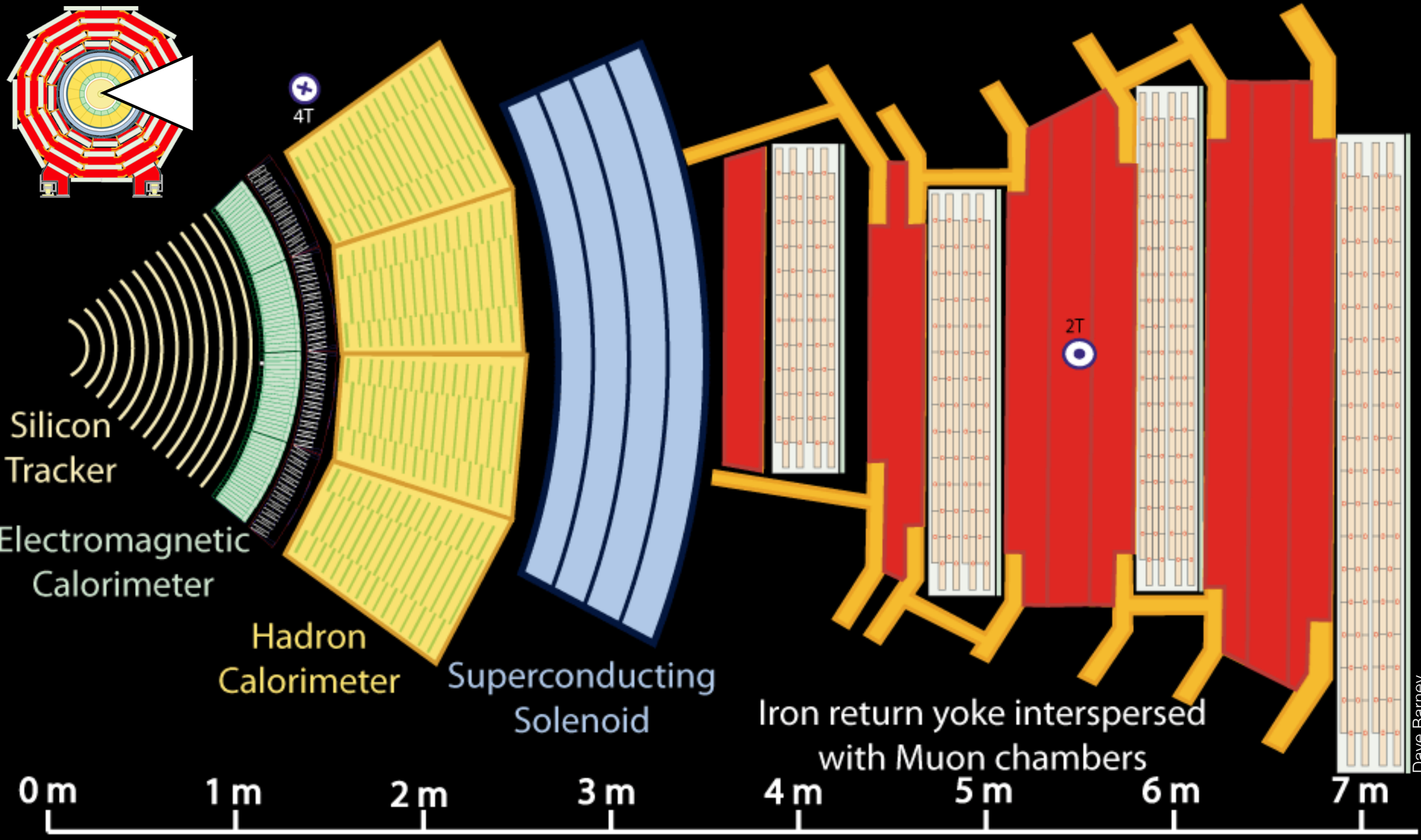
Major USA involvement, led the had. calorimeter

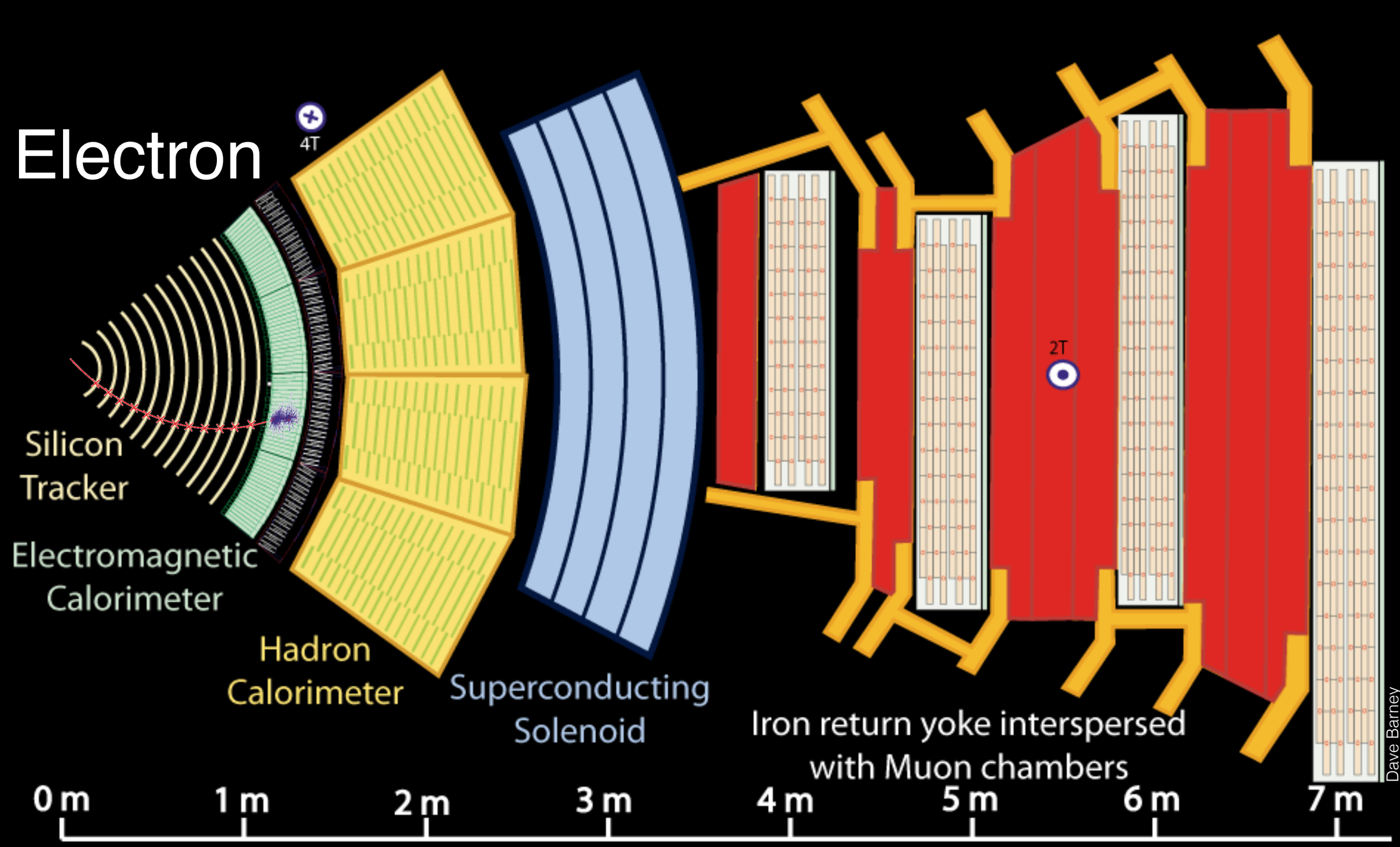
Outside solenoid:
Gas-based muon detectors



USA built most of the endcap muon system (cathode strip chambers)




4T
2T
Silicon
Tracker
Electromagnetic
Calorimeter
Hadron
Calorimeter
Superconducting
Solenoid
Iron return yoke interspersed
with Muon chambers
0 m
1 m
2 m
3 m
4 m
5 m
6 m
7 m
Dave Barney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0 m
1 m
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4 m
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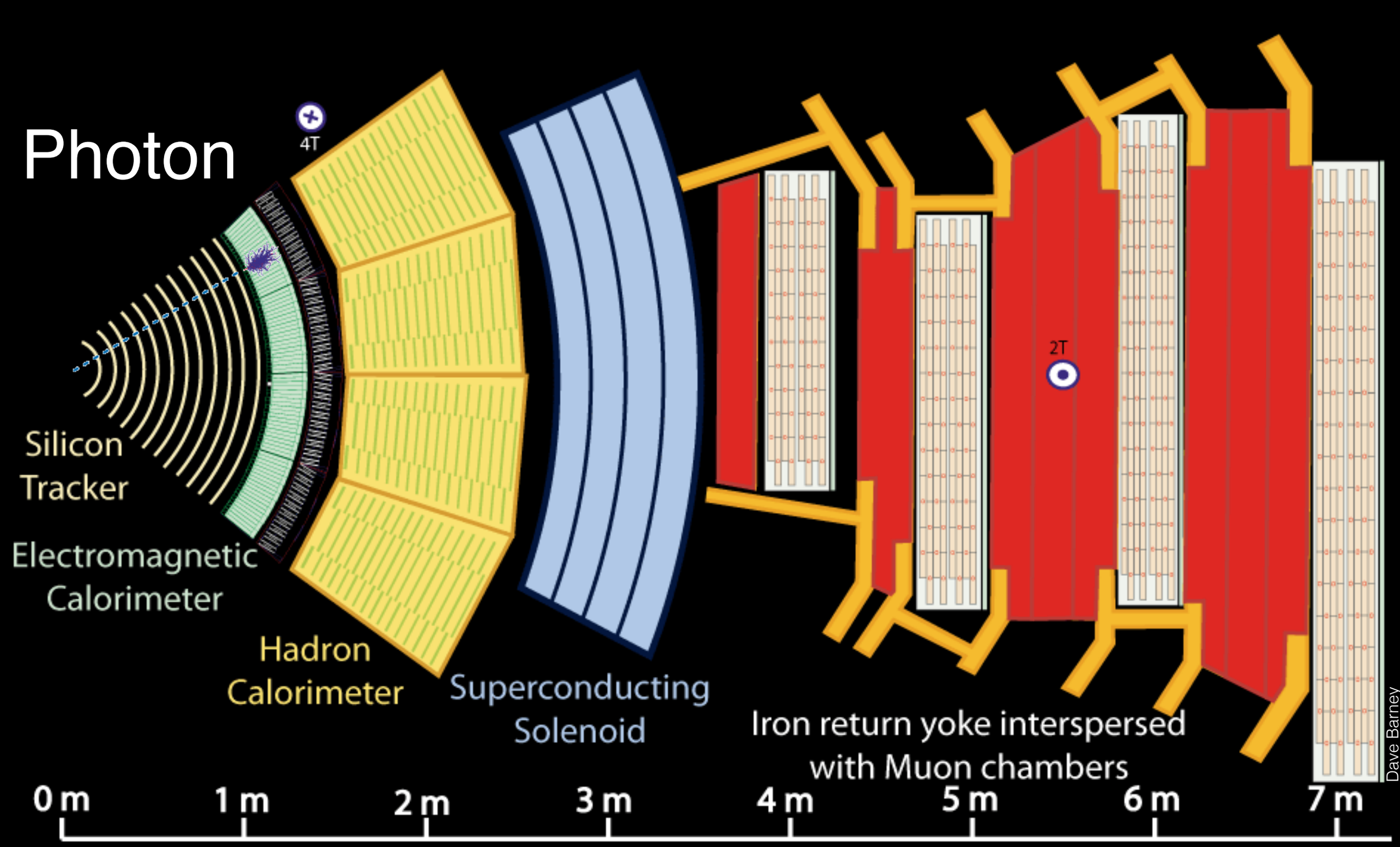
7 m
Key:
Electron
Dave Barney

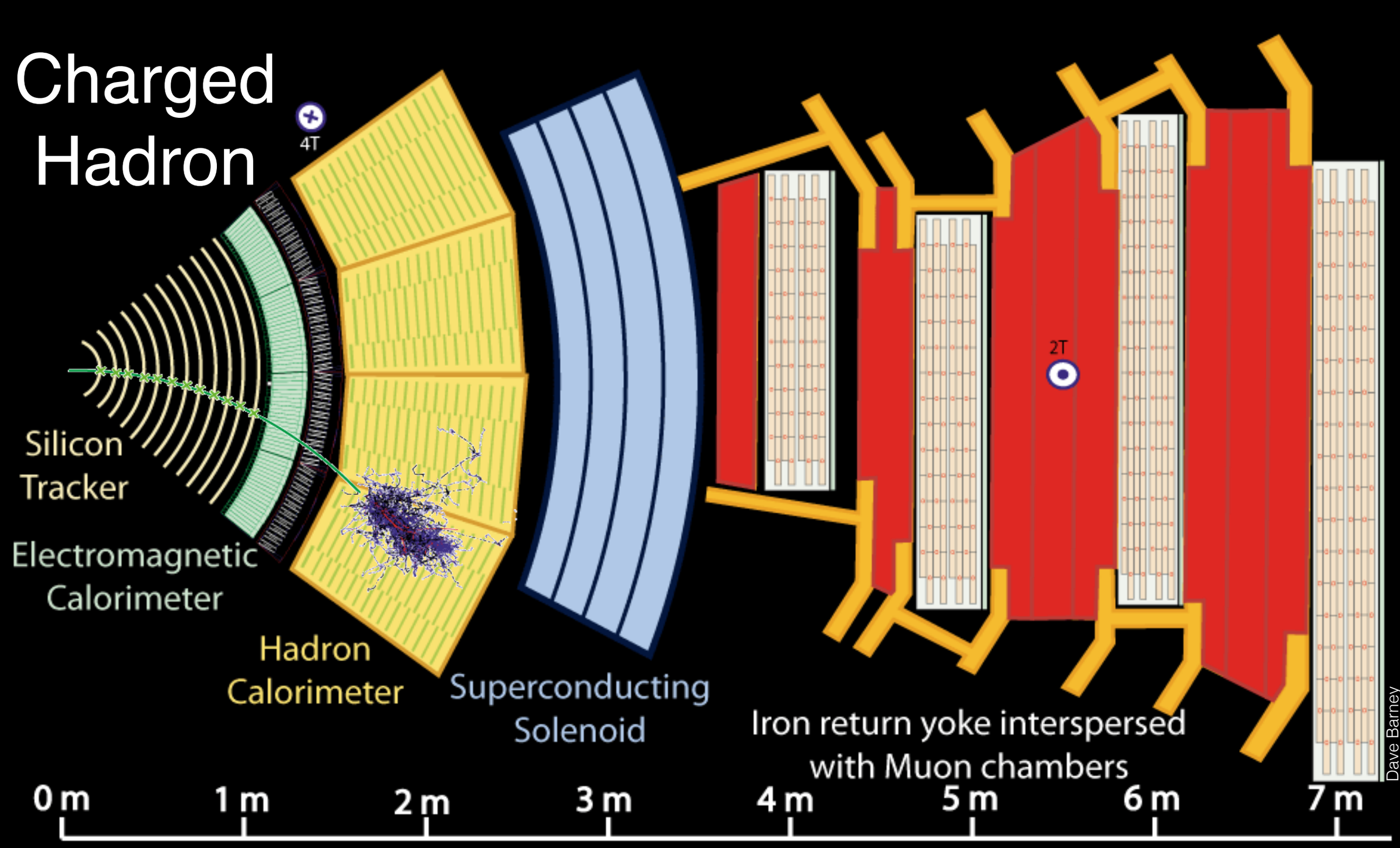
Photon



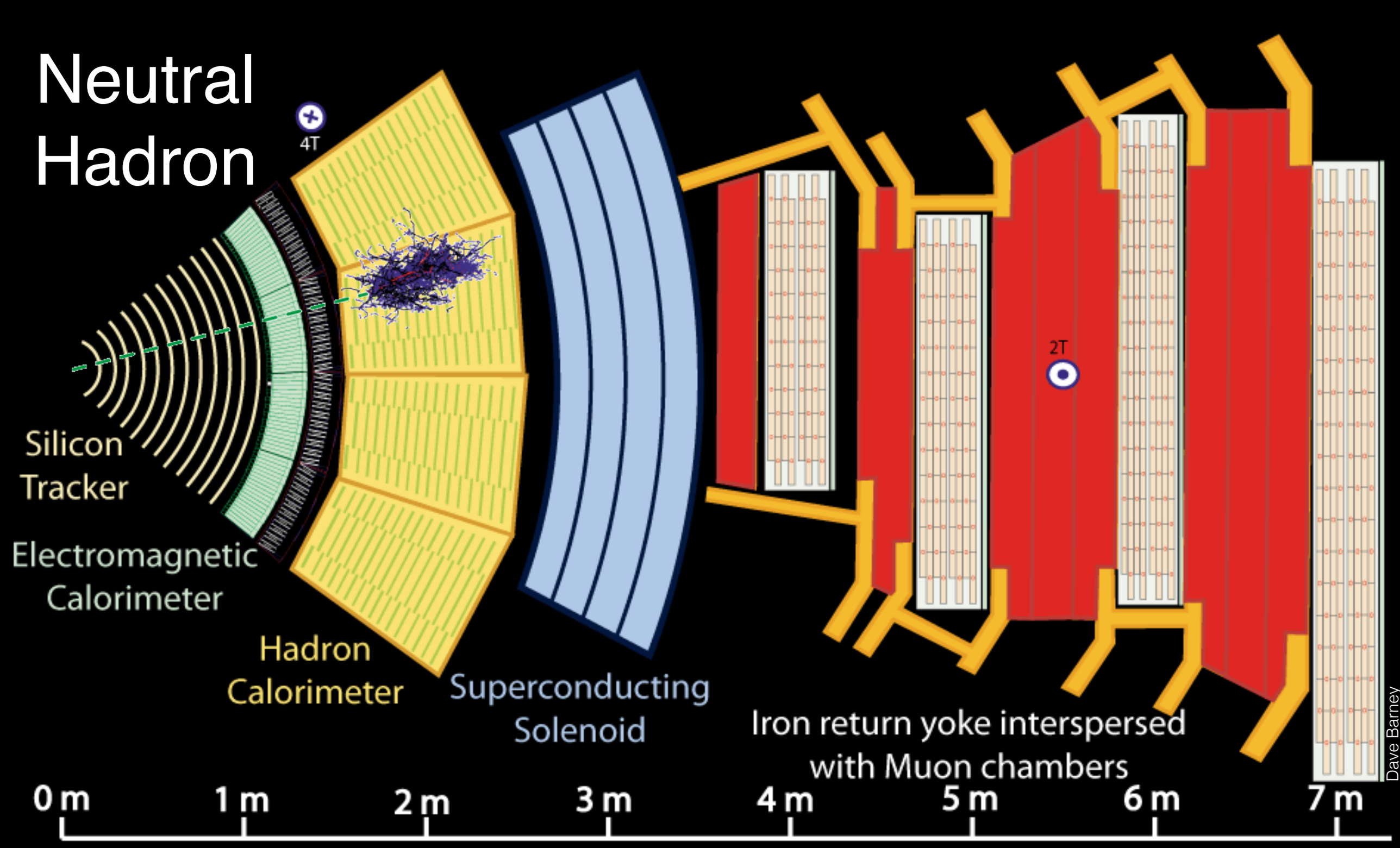
Key:

----- Photon

Charged Hadron



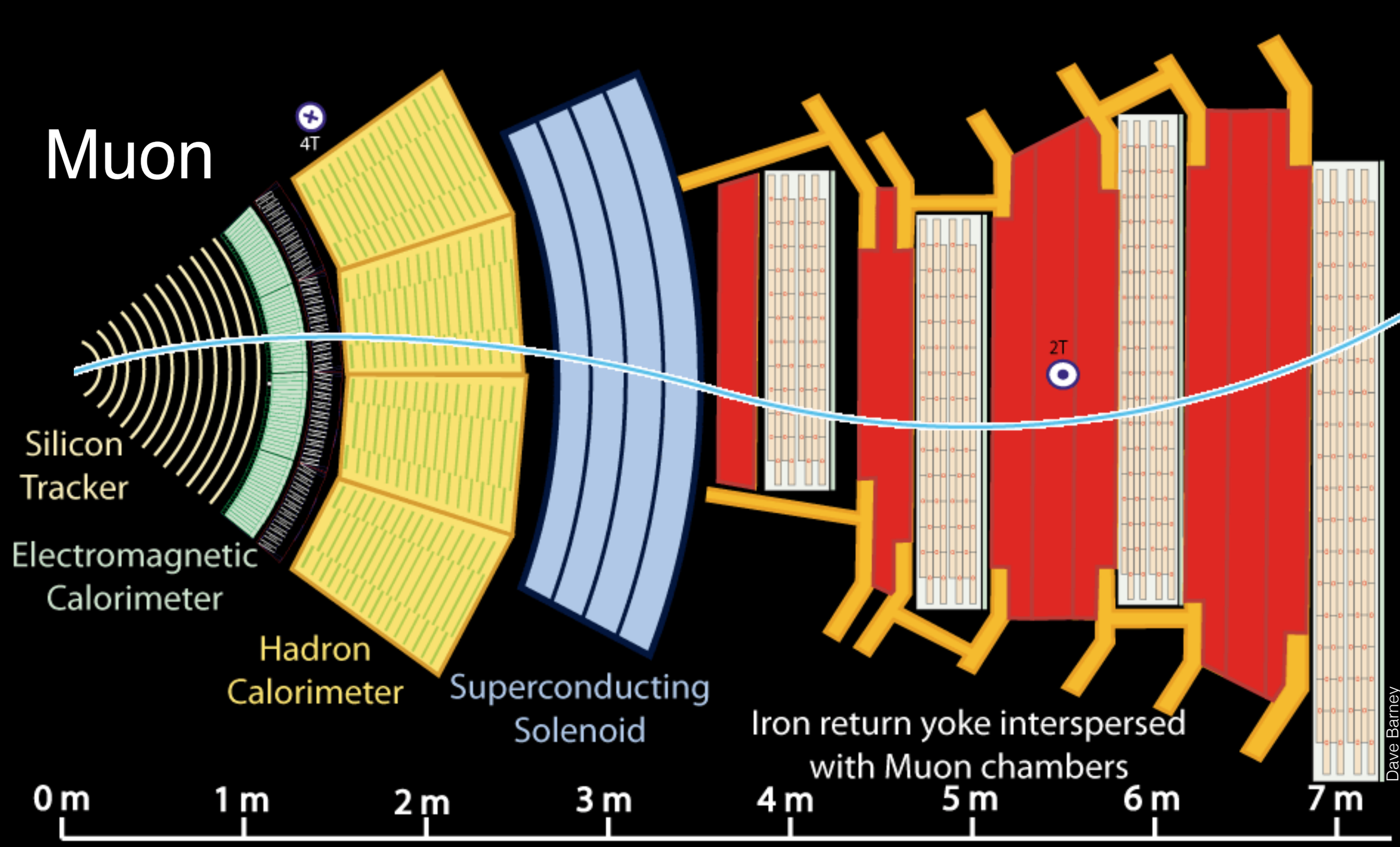
Neutral Hadron



Key:

– – – · Neutral Hadron (e.g. Neutron)

Muon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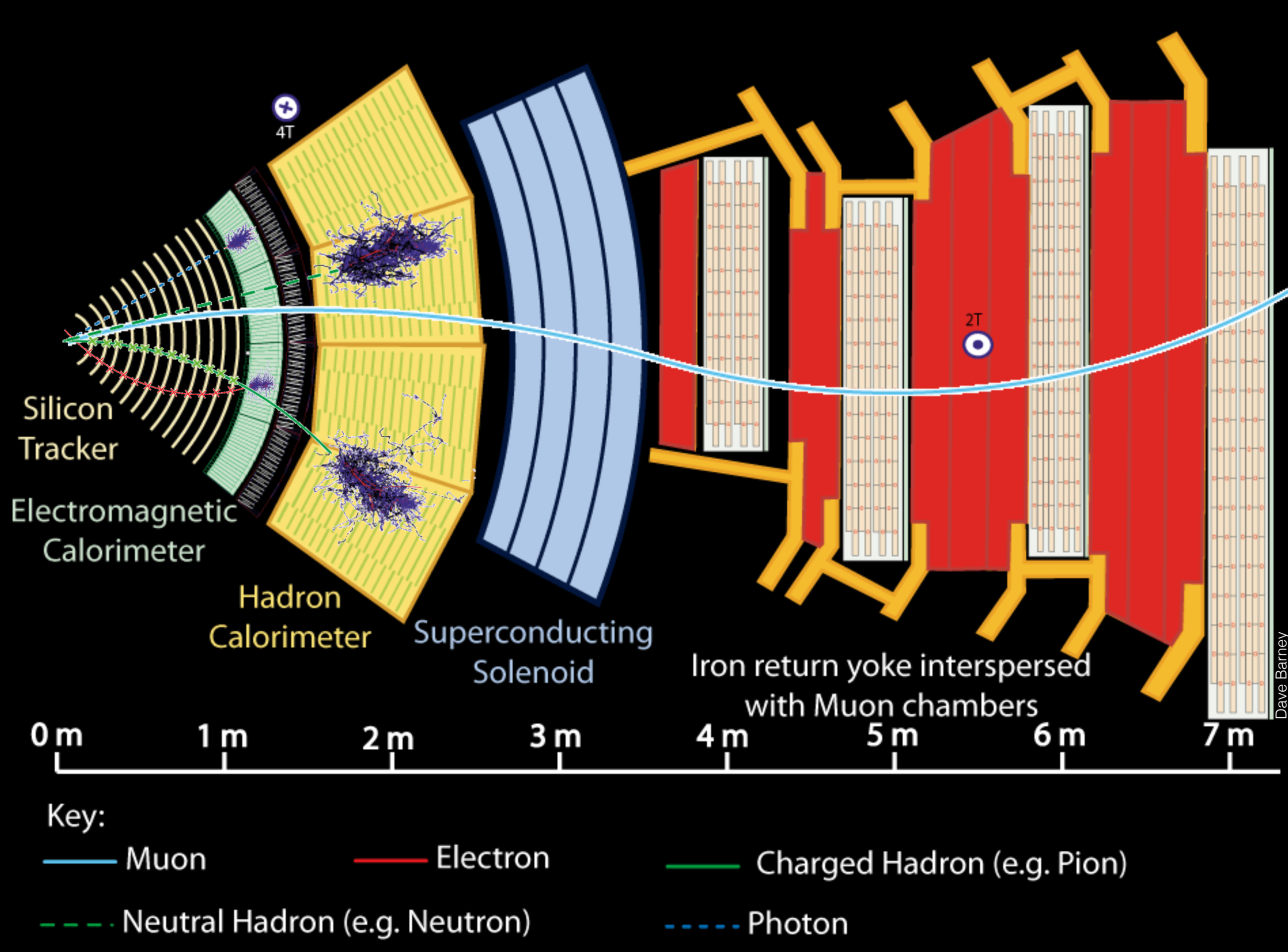
Dave Barney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0 m
1 m
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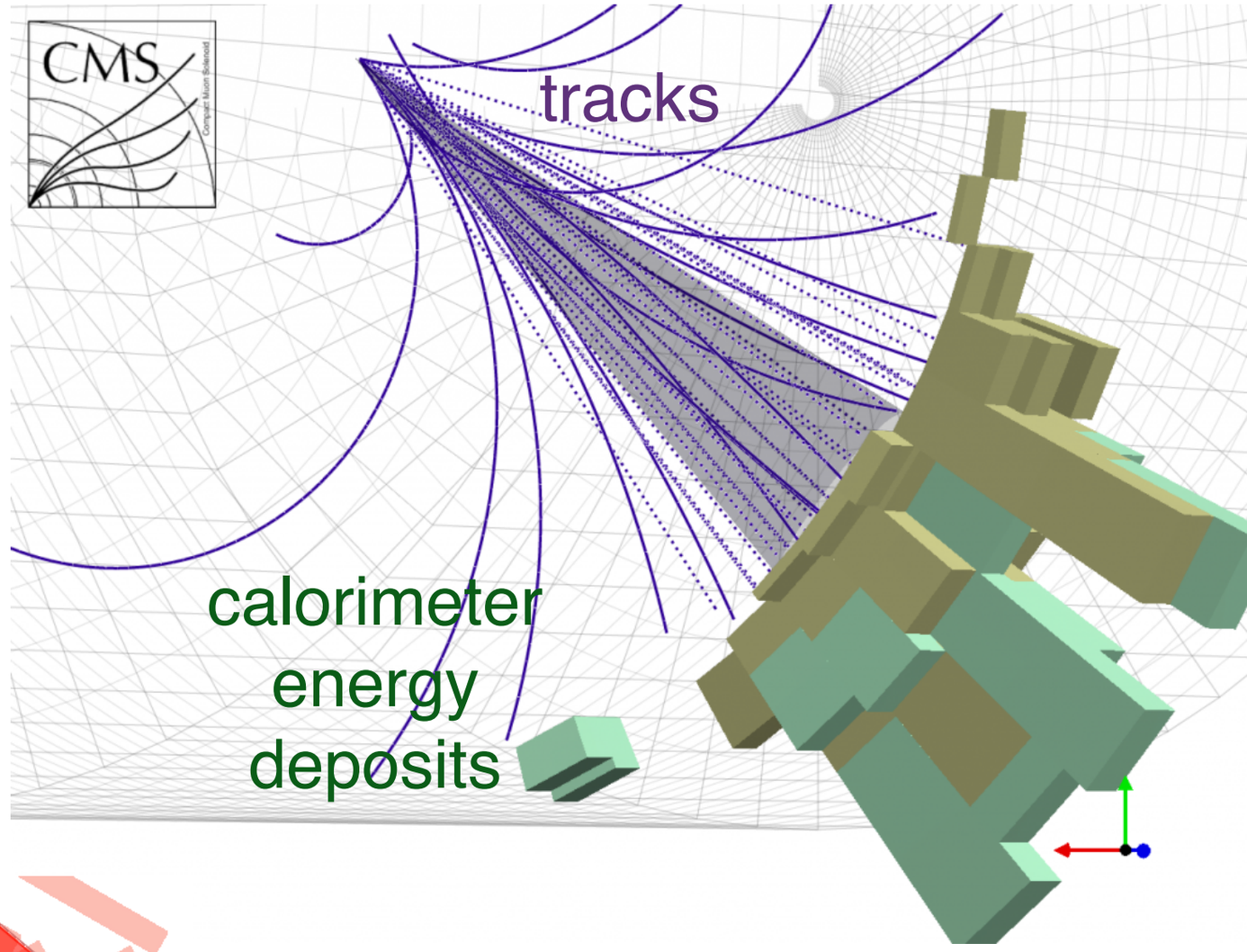
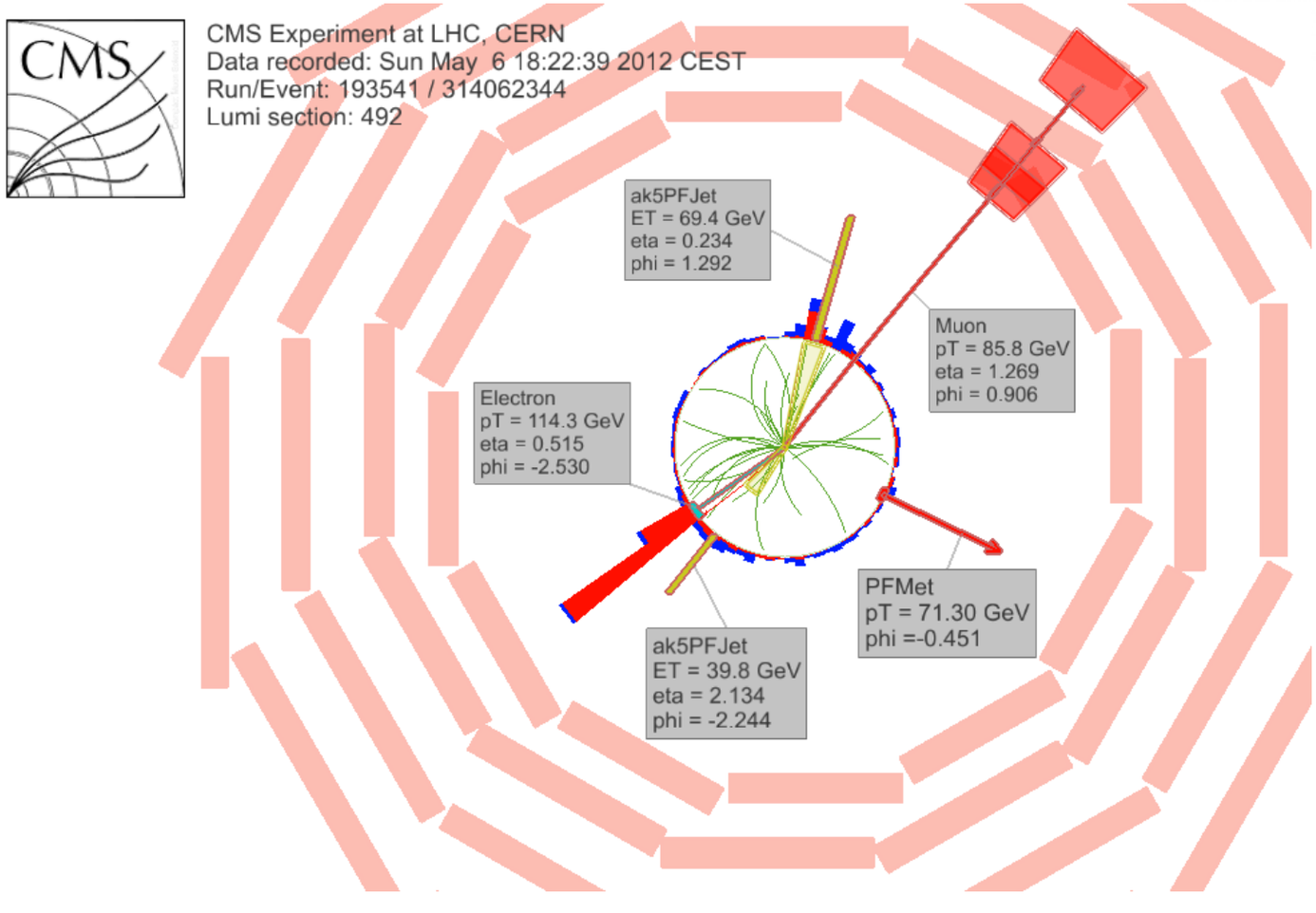
7 m
Key:
Muon
Electron
Charged Hadron (e.g. Pion)
Neutral Hadron (e.g. Neutron)
Photon
Dave Barney

From these, we can reconstruct more complicated objects, such as **jets**





Zero total momentum in transverse plane $\sum_{\text{all}} p_T = 0$

Missing transverse momentum (MET) from e.g. neutrinos or dark matter inferred from detected objects $\text{MET} = -\sum_{\text{detected}} p_T$

40 MHz collision rate

pass/fail

100 kHz readout

pass/fail

500 Hz stored

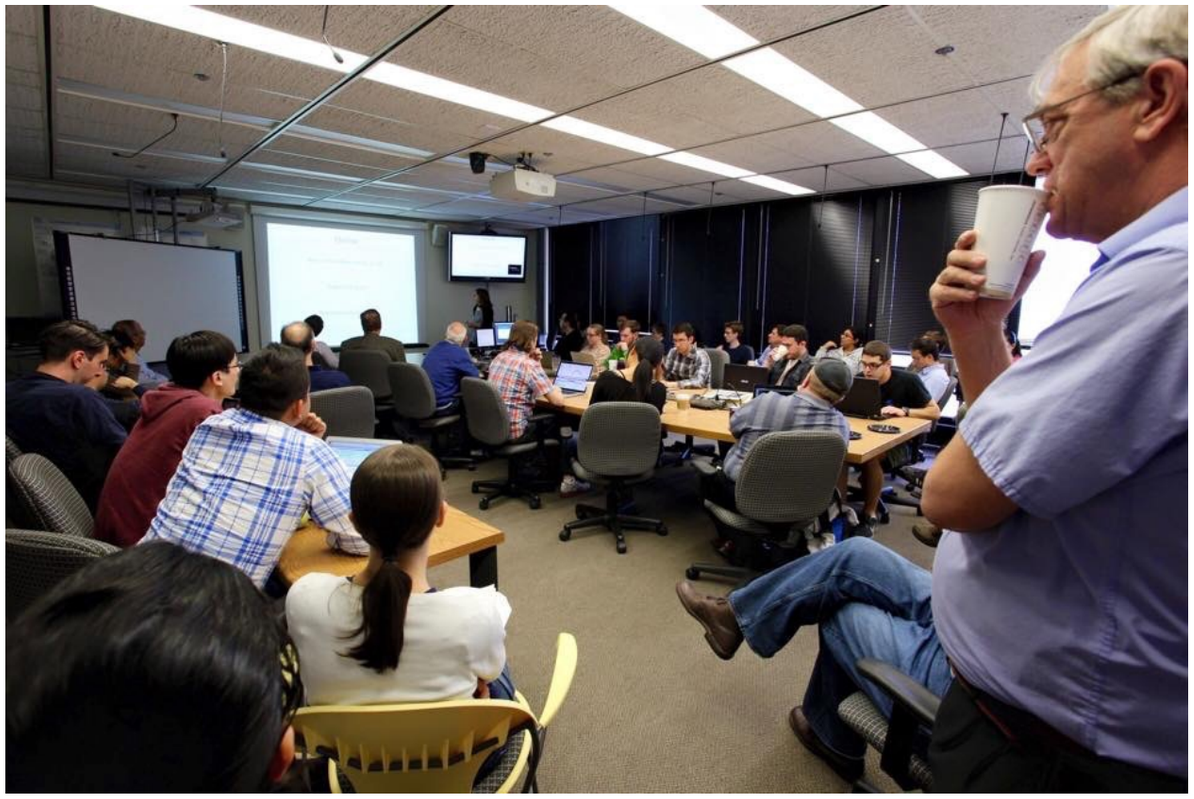
"Level-1 Trigger"
(custom electronics, many from USA)

"High Level Trigger"
(computing farm, USA involvement)

Data acquisition and distribution

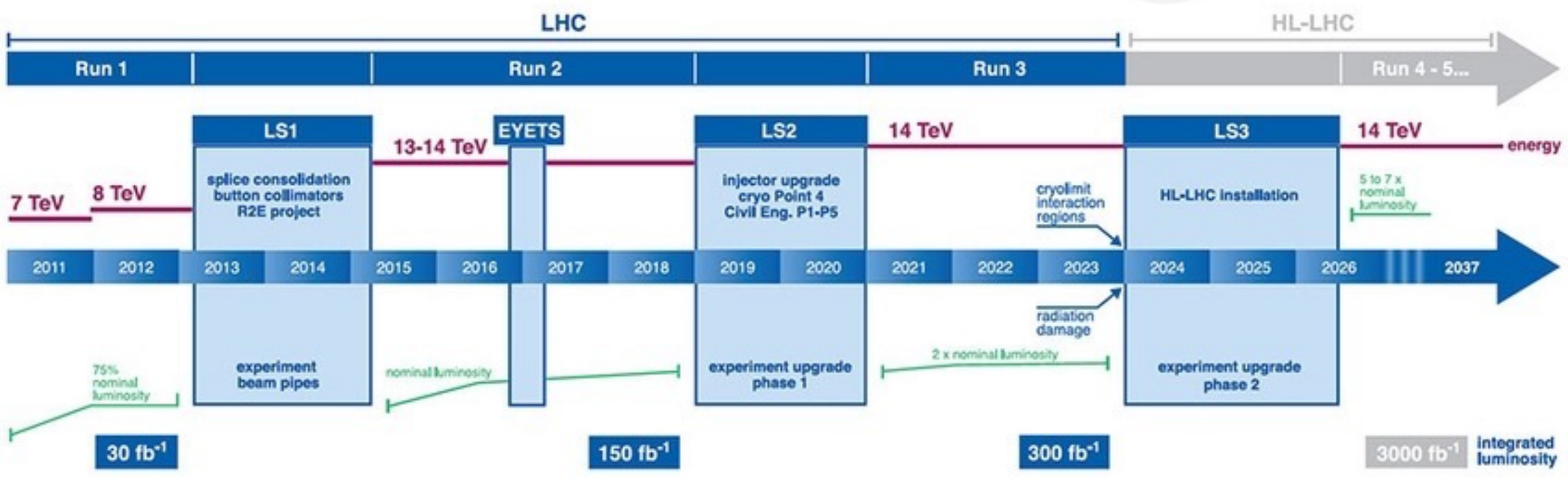
- 1 Megabyte/event
- O(10) million Gigabytes/year
- Stored around the world
- Analyzed with grid computing

Fermilab's LHC Physics Center



- 700 users of LPC computing resources
- 350 users and 100 residents from 50 universities gather here to collaborate
- Regular discussions, talks, workshops, and schools

LHC / HL-LHC Plan

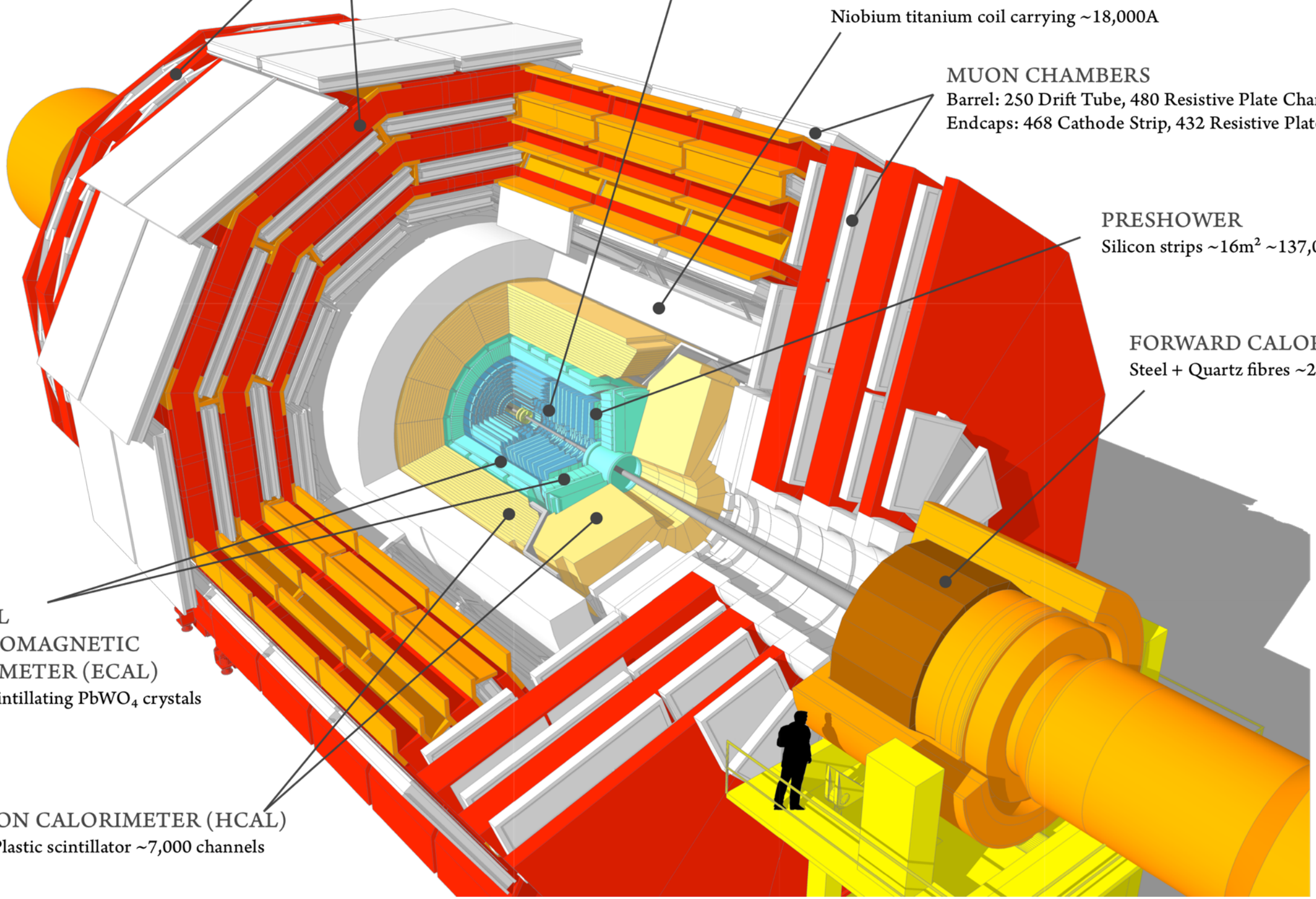


Today

backup

CMS DETECTOR

Total weight : 14,000 tonnes
Overall diameter : 15.0 m
Overall length : 28.7 m
Magnetic field : 3.8 T



STEEL RETURN YOKE
12,500 tonnes

SILICON TRACKERS
Pixel (100x150 μm) ~16m² ~66M channels
Microstrips (80x180 μm) ~200m² ~9.6M channels

SUPERCONDUCTING SOLENOID
Niobium titanium coil carrying ~18,000A

MUON CHAMBERS
Barrel: 250 Drift Tube, 480 Resistive Plate Chambers
Endcaps: 468 Cathode Strip, 432 Resistive Plate Chambers

PRESHOWER
Silicon strips ~16m² ~137,000 channels

FORWARD CALORIMETER
Steel + Quartz fibres ~2,000 Channels

CRYSTAL ELECTROMAGNETIC CALORIMETER (ECAL)
~76,000 scintillating $PbWO_4$ crystals

HADRON CALORIMETER (HCAL)
Brass + Plastic scintillator ~7,000 channels